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Economics and Transitions: Lessons from Economic Sub-disciplines[1]

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Abstract
Currently, there is much interest in stimulating or 'speeding up' socio-technical transitions to sustainable systems, most notably in the sectors of energy, transport and agriculture. This essay attempts to assess whether and how 'transition' type problems and issues are being addressed in the various sub-disciplines and methodological approaches of economics. This allows us to identify concepts, ideas, theories and empirical methods in economics that are suitable for inclusion and elaboration in 'transition research'. Surprisingly, we find that many sub-disciplines of economics have in one way or another addressed problems similar to transitions. Our main conclusion therefore is that economics offers a rich palette of ideas that may be useful for transition research. Studies on development stages, long waves, technological path-dependency, conflict resolution, public investments, emergence of institutions and, transitions from communist to market-democracy systems seem especially relevant to the study of transition. Although mainstream economics conflicts in certain ways with the approach called for by many involved in transition research, we show that economics certainly has something to offer to the study of transitions.

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1. Introduction

Recent discussions of sustainable development often present the concept of 'transition' as a generalized notion of system innovations (e.g., Board on Sustainable Development, 2000; Raskin et al., 2002; Elzen et al., 2004; Geels, 2002, 2005; Rotmans, 2003; Smith et al., 2005). A transition comprises a society-wide change that goes beyond single sectors and involves fundamental and interrelated changes in technology, organisation, institutions and culture. The notion of 'transition' can be viewed as a response to the problem associated with the fact that many studies of sustainable development are restricted to formulating or portraying a hypothetical and utopian sustainable system (i.e., a 'blueprint') while it remains unclear how such a system can be realized. The shifting of the focal point from a sustainable 'end state' to the transition process that transforms the current, unsustainable system into a sustainable state, adds realism and policy relevance to the analysis. Transition studies are thus aimed at assessing the processes that initiate, foster and direct transitions as well as the barriers against transitions.

In the Netherlands, the national government has made a commitment to stimulate transitions in energy, agriculture, built environment and transport. In addition, a 20 million € research programme (KSI) has been established to increase knowledge about transitions. The programme aims to generate both fundamental knowledge about transition processes, including typologies of transitions, causal mechanisms, and ways in which transitions and related co-dynamic processes can be studied. In addition, it aims to produce practical knowledge that can be used to the benefit of ongoing transition experiments in the Netherlands, which are fostered by the ministries of economics and the environment. Both aims are realized through three areas of research:[2]

1) Historical research of past transitions, which allows drawing theoretical as well as policy lessons. In particular, this tries to learn about the teleological nature of past transitions, the role of co-dynamics of sub-systems, visions, expectations, and collective action in bringing about transitions.
2) Systematic analysis and monitoring of current transitions and analysis of hypothetical, future transitions, with a special focus on mobility, health care and, agriculture.
3) Research on the governance (steering and management) of transitions, looking at the co-dynamics of sub-systems.

Transitions can be conceptualised as non-linear processes of change, involving four stages, namely predevelopment, take-off, acceleration or breakthrough, and stabilisation (Rotmans, et al., 2001). Steering of transitions is difficult if not impossible, as they involve complex interactions between subsystems (co-dynamics) of the social-economic-technological-institutional system. Even when a government commits itself to a certain transition, it cannot control the transition in a top-down manner, if only because it itself is a central part of the change.

Kemp et al. (2006) have developed a model of transition management based on such things as 'dynamic agendas' and 'adaptive programmes'. Transitions are regarded here as involving changes at three levels, namely of niche, regime and (socio-technical) landscape. A transition requires synchronicity and interaction of developments in different domains, which often involves mutual reinforcement (Rotmans, et al., 2001). Within the multilevel scheme, producers are part of a production regime and a technological regime based on a certain body of knowledge with links to science and tacit elements. Users are part of a user regime, characterised by income, (changing) preferences, habits, capabilities and modes of social interaction. They are constituted (configured) by certain capabilities, values, beliefs and roles. In addition to producer, user and, technology regimes, there are regimes of policy, science, socio-cultural activities and, market functioning. Developments in one regime influence developments in another regime

[2] For an overview of KSI projects see http://www.ksinetwork.nl/?content=projects.

(Geels and Kemp, 2005), which leads to co-dynamics or even coevolution (see Section 3.2). Niches are domains where radical innovations emerge. In other words, they act as 'incubation rooms' for radical novelties, shielding them from mainstream market selection, acting as stepping stone for further change (Schot, 1998). The macro-level is formed by the socio-technical landscape, which refers to aspects of the exogenous environment. This includes macroeconomic and international conditions, politics, cultural and normative values, environmental problems and scarce resources. It further includes the material and spatial configurations and arrangements of cities, factories, and physical (road and energy) infrastructure (Rip and Kemp, 1998; Geels, 2002, 2005).

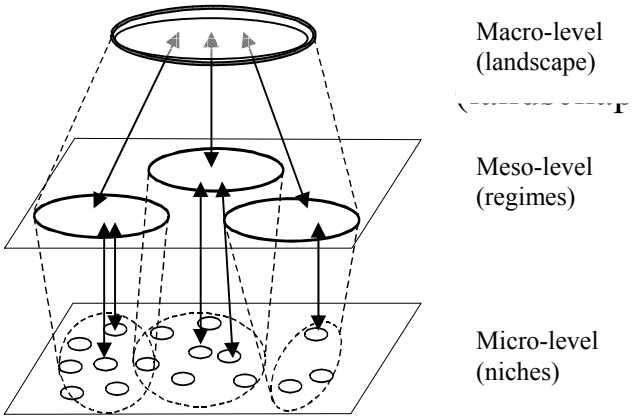

Figure 1. Interaction between different scale-levels
Source: Geels (2002).

There are different types of transitions. History depicts both relatively large and small transitions. Examples of large transitions include the invention and spread of fire control, the rise of agriculture, the Industrial Revolution and, the emergence of mass-production/consumption. Smaller transitions are the Green Revolution in agriculture, the electrification of society, various transitions in transportation (e.g., horse/wagon to car) and, certain energy transitions (e.g., from coal to gas). The notion of (a small) transition may also be regarded to cover transformations in human communication (e.g., mobile phone, email, internet), and work organization and manufacturing (i.e., from handcraft to mass manufacturing and flexible production). Finally, transitions have spatial dimensions or repercussions: cities and regions go through transitions as part of wider, global transitions; associated with this, trade patterns between regions and countries change. Kemp and Rotmans (2005) distinguish two types of transitions: goal-oriented transitions and evolutionary (non-teleological) transitions. Geels and Schot (2005) make a distinction between five transition pathways, namely transformation, opening up of new functional domain, technological substitution, de-alignment and, re-alignment. In addition, one can identify a number of challenges in analyzing transitions. See Table 2 in Section 4 for further illustration.

To date, economists have not contributed much to the elaboration of the notion of 'sustainability transitions'. Nevertheless, they traditionally have devoted much attention to the study of long term growth and development as well as to the (optimal) planning of these. In addition, they have developed policy theories based on incentive mechanisms, which have also had wide application to environmental and resource regulatory problems. Economists have stressed that in many (but not all) circumstances decentralization through price incentives gives the best outcomes from a social welfare perspective. The various mainstream economic theories have not directly addressed transition challenges like path-dependence, lock-in, diversity of options, bounded rationality and, uncertainty. In this sense, there is a gap and even a conflict

between mainstream economics and the transition paradigm. Although we pay attention to this possible conflict, the current paper adopts a constructive approach by examining which useful ideas and suggestions for transition research can be derived from the rich literature on economics, both within mainstream (neoclassical) and heterodox economic schools. In particular, we will try to collect the most exciting ideas from a range of possibly relevant sub-disciplines of economics. In addition, we will examine the relevance of methodological approaches common in economics to address transition issues.

Even though the specific notion of transition is not used much in economics, several economic concepts and terms bear close relationship to it. Examples are development, growth, structural change, (system) innovation and, transformation. So far, the term 'transition' has appeared in only three areas of economic research. In theoretical, dynamic models of growth, a transition is sometimes used to denote the change from one state to another stationary (equilibrium) state. This resembles some of the interpretations commonly attached to 'transition' in the context of sustainable development, notably the association with a major technological innovation. A second area in which the notion 'transition' has been used is the study of processes characterizing the transformation from a planned to a market economy (notably, the former communist USSR and Eastern-European countries). A third, somewhat related field of research in which the term 'transition' is employed, is that of development economics, which analyses the conditions under which poor, rural countries can change into modern market-based economies, characterized by a more educated labour force, a more balanced and elaborate sector structure, with well-functioning markets, and less dependence on resource exports and foreign aid by rich countries.

This illustrates that the idea of transition is not entirely new. Moreover, transitions are not hypothetical constructs: history is full of them. This suggests a potentially important role for (economic) historical analyses. The main difference between many historical transitions and the ones envisioned in the context of a sustainable development is that whereas the first type are with few exceptions autonomous and unintended, the latter arguably require purposeful public guidance and interference. We will suggest here that the discipline of economics can provide useful insights about the latter. This is not surprising perhaps in view of its long-standing tradition of dealing with concrete policy questions – witnessed by, among others, economic sub-disciplines such as environmental and public economics.

The structure of the paper is as follows. Section 2 assesses the main methodological approaches and sub-disciplines of economics that contain potentially relevant ideas on transitions. Next, Section 3 presents a selection of the most promising approaches and sub-disciplines with a brief discussion of their core notions and insights. Section 4 summarizes the insights by linking transition challenges to economic theories and concepts. Section 5 discusses the potential conflict between mainstream economics and the 'transition governance paradigm'. Section 6 provides a summary and conclusions.

2. An overview of relevant economic approaches and sub-disciplines

This section attempts to assess various ideas (i.e., concepts, theories, approaches and insights) from the broad spectrum of economics that have the potential to benefit the recent, emerging thinking on transitions. Such ideas may contribute to an improved understanding of transition phases and processes, elements of transition management, and barriers to transitions. For this purpose, we identify two levels of organisation within the discipline of economics.

The first level of organisation focuses on the *methodological starting point*. This includes:

- neoclassical (micro)economics (including partial and general equilibrium theory and game theory),
- macroeconomics (including various ´schools´ of thought, such as new and post-Keynesian economics, new classical economics, supply side economics, disequilibrium theories and monetarism),

- classical economics (internally heterogeneous – linked especially to early economists such as Adam Smith, Thomas Malthus, David Ricardo, Karl Marx and John Stuart Mill), and,
- various (other) heterodox schools (e.g., behavioural economics, evolutionary economics, Austrian economics, Sraffian economics and institutional economics).

The second level of organisation focuses on the *sub-disciplines*. The following list outlines the sub-disciplines considered most relevant for the purpose of transition research (core issues and concepts are indicated in brackets):

- business cycle theory (long waves),
- development economics (micro, macro, industrialization, institutional arrangements, international linkages, development planning, trade policy),
- economic growth theory (endogenous growth, multisectoral growth, comparative studies of countries),
- economic history (general, technological, industries, geography and regions, institutions),
- economic studies of transition economies (former socialist/communist countries),
- economics of disasters (disaster as unlocking a system),
- economics of information (decision-making under uncertainty and imperfect or asymmetric information, learning theories, search, network formation),
- economics of technology (innovation systems, positive externalities, diffusion, intellectual property rights, subsidies),
- environmental and energy economics (regulation, resource curse or Dutch disease, resource pricing, and extraction),
- industrial economics (market structure, innovation strategies, rent seeking, cooperation, complementary products, networks, vertical integration, and demography of industries),
- international economics (trade, location, cooperation, innovation and international diffusion),
- marketing (life cycle of products, and market and innovation strategies),
- population economics (interaction between individual choices, economic development and demography),
- public economics (public goods, public investment, public R&D, infrastructure, club theory, public and social choice, conflict resolution), and,
- spatial economics (regional diversity, spatial isolation, spatial diffusion, agglomeration theory, new economic geography, economic effects of infrastructure).

In the next section we provide a brief overview of core aspects for a select number of methodological approaches and sub-disciplines listed above, judging each against the context of the potential for transitions. Section 3.1 focuses on methodology and, Section 3.2 on sub-disciplines.

3. A selection of economic insights with potential relevance for transition research

3.1 Methodological approaches

Classical economics

Classical economists' concern with historical change suggests relevance for transition research. They study the mechanisms of transformations occurring in economic and social life. Their economic analysis is mixed with sociological analysis of social relations (struggle). The multidisciplinary nature of this approach to analysis explains why early economists like Malthus and Marx are considered 'early' sociologists by those working in sociology.

David Ricardo and John Stuart Mill regarded the economy as moving towards a steady state. From Ricardo's point of view, this was due to diminishing returns to increasingly marginal land used for agriculture, and from Mill's point of view, it was due to diminishing returns to utility. Daly (1977/1991) emphasized the notion of a steady state economy, later referred to as an

environmental sustainable economy, with a minimal material and energetic throughput and a stable population. Malthus believed population control was the major problem, as food scarcity would become urgent, and as such, he proposed restraint as the most effective and realistic approach. Classical economists generally believed that land was (still) an important and scarce production factor (Hubacek and van den Bergh, 2005). This changed dramatically due to industrialization, which marginalized agriculture. The new point of view was reflected in the neoclassical economics paradigm by a shift in emphasis to the production factors, labour and capital, resulting (initially) in a disregard for the fundamental role of natural resources.

Grand development theories: Marx, Schumpeter and Rostow

Classical and other economists have proposed grand development theories. Karl Marx, Joseph Schumpeter and Walt Rostow (1960) are the most important ones. They combined an interest in theory with an interest in history, not just economic history but also social and political history. They did not focus on economic change at the margin but on how different elements of historical change are mutually connected and on the discontinuities rather than trend-like changes. Marx and Schumpeter both believed that capitalist systems would go through a transition ending in a socialist system. Marx developed a political transition theory with a period of proletarian dictatorship in the transition from capitalism to socialism. Class struggle (a sort of group theory) was a crucial mechanism in his theory.

Schumpeter (1934, 1939, 1942) thought that the neoclassical notion of equilibrium was problematic, as he regarded capitalism as a process that can never be stationary. Schumpeter´s view of capitalism was built around the notion of "creative destruction", denoting a "process of industrial mutation (…) that incessantly revolutionizes the economic structure *from within*, incessantly destroying the old one, incessantly creating a new one" (original italics, Schumpeter, 1976, p. 83).

Like Marx, Rostow (1960) developed a multi-stage theory of development, not towards a communist society but towards a consumer society. His five-stage framework described the stages that poor, developing countries must pass through in order to become modern market economies. These stages comprise the traditional society, the preconditions for take-off, the actual take-off, the drive to maturity, and high mass consumption. This theory resembles life-cycle theories common in marketing, aimed at describing the development of products and markets. Rostow set out a number of conditions that were likely to occur in investment, consumption and social trends during each stage. The stages, the length of transitions periods and the conditions may vary from country to country and region to region. Rostow attached great importance to political change, most notably the building of an effective national state and commitment to modernization, as an important precondition for take-off. Maturity (mass consumption) is reached after some 60 years after the beginning of take-off. The impetus for growth comes from new technology, diffusing across various sectors, ultimately leading towards the production of consumer goods and services as leading sectors. Rostow´s systematic, detailed theory certainly deserves serious attention from transition researchers. A similar stage model of industry development around technology evolution focusing on skills, investment and location is offered by Perez and Soete (1988). Today however many economists are criticial about the view of economic development moving towards stationary states, not just neoclassical economists but also evolutionary economists such as Harvey and Metcalfe (2005) who regard capitalistic systems as restless and unsettling.

Neoclassical economics

The dominant methodology within the current discipline of economics is neoclassical economic theory. Central to it is the assumption that agents – households, firms and public agencies – act rationally or individually optimally (i.e. they consistently maximize a given utility or profit function). Neoclassical economics focuses its attention on market relationships, as such its policy

theory derives from the idea that market failures, causing a deviation between market equilibrium and a social welfare optimum, should be appropriately corrected. Suggestions resulting from this approach that are relevant to the understanding of transitions can be summarized as follows (see also den Butter and Hofkes, 2004):

- Prices (neglected in many perspectives on transitions) coordinate economic choices, including demand, supply, investment in capital and outlays on R&D.
- Negative externalities due to environmental pollution and positive externalities of R&D and innovation need to be internalized.
- Changes take the form of smooth trends (growth theory, rational expectations) and smooth substitution process (equilibrium theory) rather than sudden breaks. Economic change is governed by prices signalling relative scarcity, including those of natural resources.
- Old, obsolete techniques are gradually replaced by new, more profitable techniques (vintage capital models).

Traditional (general) equilibrium theory is a special case of game theory, where the latter generalizes types of human interactions, not only market, possibly repeated, but strategic (expectations about others´ behaviour). Transitions can be conceptualised as non-zero sum, dynamic (sequential) and, coordination games. A number of insights from game theory relevant to transitions follow. A central insight of game theory is the prisoner dilemma: individual rationality combined with non-cooperation can lead to an outcome that is sub-optimal from an individual and a social perspective. Repeated interaction, negotiation (a convention, standard or institution) or coordination (information sharing, or exchange and complementary specialization), can assist in solving this type of problem. Coordination games can be characterized by multiple equilibria. Any observed or resulting equilibrium is then a matter of arbitrariness or randomness, but may be purposefully stimulated by agreeing on norms or setting uniform standards. Evolutionary game theory has been developed partly in response to this ´equilibrium selection´ problem. Transitions involve many strategic interactions between different agents which might be caste in game theoretical terms.

Many of the specific insights arise from the application of general neoclassical economic theory in sub-disciplines, as examined in the next section. In addition, in Section 5, we will consider the potential conflict between mainstream neoclassical economics and transition thinking, as noted by some transition researchers.

Behavioural economics

Whereas neoclassical economics assumes that individual agents are rational, a new school, behavioural economics, works along different lines. Behavioural economics, overlaps with and is motivated by experimental economics and economic psychology. The three approaches have pointed convincingly at the shortcomings of the neoclassical economics approach on the basis of philosophical and theoretical arguments as well as empirical and experimental evidence (e.g., Caldwell, 1984; Conlisk, 1996). In response to this, a range of alternative models have been proposed to address particular aspects of bounded rationality (Camerer et al., 2003). Transition research calls for studies addressing barriers to change, including those relating to individuals and organizations making decisions characterized by bounded rationality

Herbert Simon was the first to systematically argue that the combination of imperfect and costly information and limited capacity of the human brain implies a procedural rather than a substantial type of rationality, resulting in 'satisficing' behaviour: individuals try to attain acceptable rather than optimal levels of welfare, profit or other indicators. From a 'hierarchy of needs' (Maslow) or lexicographic preference perspective it is argued that needs have a hierarchical order. For instance, higher needs, such as the desire for music, would not appear before the lower needs, like satisfying hunger, are satisfied. Empirical happiness or subjective

well-being research has further established that humans adapt to changing circumstances (preference drift) and value relative (income) positions and status goods (reference drift, rivalry in consumption) (van Praag and Ferrer-i-Carbonell, 2004). Imitation (bandwagon effect) is related to this, most notably with regard to conspicuous consumption or status goods. In addition, our social behaviour is complex. Penn (2003) notes that environmental regulation should, for instance, take social interactions (e.g., reputation effects) into account. This is consistent with the findings of economic psychology and experimental economics, and of group selection theory (Henrich, 2004). Group phenomena can be linked to a variety of social – non-selfish or other-regarding – preferences: reciprocal fairness, inequity aversion, pure altruism, altruistic punishment, and spite or envy (Fehr and Fischbacher, 2002).

Various theories deal with behaviour under uncertainty, prospect theory being the most influential one. Motivated by experiments, it stresses the asymmetry with which individuals perceive gains and losses. 'Habits and routines' are often regarded as a straightforward approach to deal with complexity and uncertainty. Finally, according to some theories, under highly uncertain conditions behaviour takes the form of imitation, an example of which is panic selling. Such imitation leads to a reduction in the diversity of individual behavioural strategies.

These various views on individual behaviour are relevant to transition research, as they provide clues to such different issues as imitation on the demand side in relation to lock-in, emergence of niche markets, investment and R&D decisions, strategic interaction of individuals, and relevant policy goals. For example, happiness research has shown that growth of individual welfare is not always equivalent to growth in consumption or income, if only because the rivalry game for status goods is at best a zero-sum game (Layard, 2005).

Evolutionary economics

Evolutionary economics is perhaps the most internally consistent and formalized alternative theory to neoclassical economics. Its starting point is formed by one or more populations of elements (agents, strategies, organizations, institutions or technologies) which are characterized by internal diversity (heterogeneity). The latter can change in two directions: it can increase through innovations and decrease through selection (adoption, imitation, diffusion) (Nelson and Winter, 1982). The model of evolution points to the cumulative nature of these changes and the associated (mostly) gradual adaptation of individual elements to their environment (possibly changing) which is comprised of economic, social and ecological conditions. Evolution thus represents a population dynamics approach to transitions.

Potts (2000) has formulated an interesting proposal for the future direction of evolutionary economics. He presents a type of axiomatic foundation for evolutionary economics. In his view, economic systems are complex 'hyperstructures' (i.e., nested sets of connections among components). Connections can represent the physical connections between components in products or machines, as well as the material and information flows between individuals or departments within an organization. In this case, economic change and growth of knowledge are in essence the process of changes between connections. One thing is evident: new products, new firms and new sectors rise and old ones disappear, while firm 'growth' and economic 'growth' are essentially processes creating new and losing old connections, as well as grouping those connections or hyperstructure dynamics. In line with the idea of changing connections, Potts calls for a new microeconomics based on the technique of discrete, combinatorial mathematics, similar to graph theory, to study the change of microeconomic connections. In addition, Potts' approach can be viewed as a fundamental discussion of the need for multi-agent or population models, also known as ´artificial life´ models. He also seems to suggest that all connections have a spatial dimension as well, implying the relevance of the 'geometry of space'.

The emergence of new levels of reality through the grouping of connections offers a refreshing perspective on transitions, similar to the way in which they are perceived in biology (e.g., from molecules to cell to multicellular organism to animal groups). Not surprisingly,

transitions are also recognized and given much attention in evolutionary biology (Maynard Smith and Szathmáry, 1995). The emergence sequence suggests increasing complexity fed by a larger degree or a higher level of specialisation, labour division and cooperation. This process might be the key to fostering transitions. The essence of evolution is that its' transitions result from self-organisation based on evolutionary principles and that regulation can only guide the evolutionary mechanisms rather than control a transition.

Next, the concept of coevolution provides a promising direction for research on transitions. In a strict sense, coevolution occurs when interactive populations evolve subject to interactions taking the form of mutual selection. In other words, two evolutionary processes are interlinked or interdependent (van den Bergh and Stagl, 2003). The resulting dynamics can be complex (irregular or even seemingly chaotic) and unpredictable (e.g., Noailly, 2003). Coevolution should be clearly differentiated from co-dynamics, which is, the interaction (e.g. negative and positive feedback) between subsystems in a larger system (van den Bergh and Stagl, 2003; Winder et al., 2005).

Attempts to elaborate the notion of coevolution in an environmental policy setting are Rammel and van den Bergh (2003), Rammel et al. (2004) and Bleischwitz (2003). A coevolutionary view is important for thinking about transitions and governance for two important reasons (Kemp et al., 2005). First, it accepts that we have cause-effect-cause loops across different scales and systems, with effects becoming causes of other developments. For example, people's needs are partly endogenous to other developments (e.g., in transport and information/communication technology). This creates irreversibilities. Second, a coevolutionary perspective sees developments in different subsystems as partially independent (relative autonomy). This means that transitions cannot be managed from the top. Transitions typically evolve, with a limited role for comprehensive control. Finally, group selection may be relevant to the understanding of transitions, as it can explain group specific norms and group formation and conflict. According to group selection theory, selection is a multilevel process, occurring both within and among groups. The outcome of this depends on the relative force of each selection mechanism. If group selection effects are sufficiently strong, then groups are adaptive. This theory is used to explain altruism, cooperation, public goods and norms in groups of sizes beyond which kin selection and (direct or indirect) reciprocal selection can work. Although traditionally strongly debated in biology, the possibility of group selection is now supported by a range of theoretical models (Bergstrom, 2002). The empirical relevance of the theory differs amongst species, while its relevance for humans has recently been convincingly argued for (Wilson, 2002). A distinction can be made between genetic and cultural group selection, representing different transmission mechanisms that are operative, and which have distinct features and speeds (see a special issue of the *Journal of Economic Behavior & Organization* vol. 53(1), 2004). For example, in cultural group selection, higher institutions such as religions and prolonged education systems may influence the basic norms of individuals (notably children). In addition, non-random assorting (joining or forming groups based on similar individual characteristics or convictions) is more common in human social-economic systems. Group size, formation and stability are critical issues when examining group selection. They may provide useful policy linkages when applying the theory, in the context of transitions, to cooperation, group competition and stakeholder groups.

Institutional economics

Institutional economics is concerned with the identification of the various institutional mechanisms that coordinate economic activity, with 'getting into grips' with the circumstances under which these various mechanisms emerge, and with the logic inherent in the different coordination mechanisms (Hollingsworth and Boyer, 1997). Institutional economics developed as a separate branch of economic theory. Within it, a common distinction is made between old

(Veblen, Mitchell, Commons) and new streams (Myrdal, North, Olson, Williamson) (see Hodgson, 1988).

Mainstream economics has generally regarded institutions as constraints that can be altered by purposeful policy and regulation. In other words, institutional change is commonly framed as a control problem rather than an endogenous phenomenon. An exception to this general rule is found in the Coase theorem which states that in the presence of negative externalities, spontaneous negotiations among rational agents can lead to socially optimal outcomes. Applied institutional economic analysis has focused on the liberalization and the removal of imperfect competition in markets (anti-cartel legislation). In addition, the creation of well-functioning new markets has received some attention, most notably in the context of environmental policy (tradable permits) and semi-public goods (telecom auctions).

The two approaches in institutional economics differ in terms of their theories of change: for 'new' institutional economists, the pursuit of economic efficiency (through competition and political struggle) causes institutions to change. North (1981, 1991) has interpreted long periods of change in these terms. The other approach (i.e., 'old' institutional economists) is less economic in its identification of mechanisms. It emphasizes the historical nature of change, the role of contingency and the non-universalistic element in micro-change. Besides markets the following modes of governance (forms of interaction and mechanisms for compliance) are distinguished: communities, networks, associations, private hierarchies and the state. The modes differ in terms of organizational structure, rules of exchange and (individual and collective) means of compliance. Networks are based more on personal relationships and trust built outside of the economic arena. Private hierarchies and the state are structures that are more hierarchical structures, based on coercion and prescriptive rules (Hollingsworth and Boyer, 1997, p. 15-16). Institutions shape but do not determine behaviour. Historical change is both the result and determinant of institutional change (duality of structure).

Institutional economics is concerned with transaction costs and trust (social capital) which are seen as important variables for explaining the link between micromotives and macro-behaviour – being an important transition topic. Institutional analysis is applied to organizations, economic sectors, values chains, and nations - all of which are relevant to transition research.

(Neo-)Austrian economics

The school of (Neo-) Austrian economics emphasizes the roundabout, multi-stage nature of production, temporal aspects of production, production processes as compositions of discrete techniques, and market processes instead of equilibrium. Both (Neo-)Austrian economics and evolutionary economics support a type of Schumpeterian competition of a different production process: an old technique is threatened and slowly replaced by a newer, more advanced, and usually more roundabout technique (i.e. involving more indirect or intermediate production connections). Such a multi-stage and multi-activity approach clearly fits within the study of transitions.

Faber and Proops (1990) propose a neo-Austrian approach with evolutionary elements, to emphasize the role of time. They allow for irreversibility of changes in the sector structure of the economy, for uncertainty and novelty, and for a teleological sequence of production activities ("roundaboutness"). The long-term relation between environment, technology and development is characterized by the following three elements:

- The use of non-renewable natural resources is irreversible in time, therefore a technology based on its use must ultimately cease to be viable.
- Inventions and subsequent innovations lead to more efficient use of currently used resources and substitution by resources not used previously.
- Innovation requires a certain stock of capital goods with certain characteristics is built up.

Faber and Proops construct a multi-sector model with the production side formulated in terms of activity analysis, which allows for the study of the effect of invention and innovation in moving from a situation with simple production activities to more complex or roundabout production activities. Roundabout activities use multiple technologies. For example, food production has become more roundabout, moving from agriculture with labour, through agriculture with labour and capital, to a large food processing industry with many intermediate deliveries. This approach is extended with the technology effects of resource scarcity as indicated above. It can then simulate economic and environmental history from a pre-industrial agricultural society to an industrial society using fossil fuels and capital. It allows for a combination of continuous changes in technological efficiency and discrete jumps in the number of sectors and interdependencies among sectors. With its original multi-stage perspective – an alternative to neoclassical economics – on structural economic change, neo-Austrian economics could provide a useful contribution to transition research.

Some other methodological approaches, notably macroeconomic growth theory, will be addressed in the next section.

3.2 Sub-disciplines

Business cycles and long waves

The phenomenon of long waves is relevant in the context of transition research. Long waves can be defined as cycles of prices, wages, outputs of specific basic commodities (e.g. energy resources, metals), foreign trade, interest rates, and various other economic variables. The notion of waves or cycles suggests an upward and downward swing, rise and decline (boom and depression).

Various types of cycles or waves have been identified (cf. Freeman, 1996) including the Kitchin cycle (40 months) related to keeping inventories; the Juglar or business cycle (7-11 years) related to adjustment of investment in fixed assets responding with delays to price changes; the Kuznets cycle (15-30 years) related to waves of migration and weather (exogenous ‘'luni-solar tides’ affecting rainfall and, in turn, crop production); and, the Kondratieff cycle (40-60 years). The Kondratiev growth cycle is perhaps the most interesting from a transition point of view because it is based on clusters of innovations.

Many different opinions have been expressed regarding the nature of long Kondratiev waves as well as their causes (Freeman, 1996). They are often regarded as being caused by major shifts in technology, also known as the emergence of a new techno-economic paradigm, which are followed by the diffusion of pervasive technologies among many sectors. Good examples are electricity and ICT. Freeman points out that the issue of long waves is contentious even among those who recognize fluctuations in economic variables over time. A deep methodological problem arises from the combination of the complexity of long-term history and the difficulty of empirically assessing the precise causality behind the long-wave phenomena. Reconstruction of historical data and statistical ‘de-trending’ (cliometrics) magnify these problems. Nevertheless, there is much to learn for transition researchers.

Freeman and Perez (1998) identify five techno-economic transitions or Kondratieff waves: (1) early mechanisation, (2) steam power and railway, (3) electrical and heavy engineering, (4) Fordist mass production, and (5) information and communication technology. For each of the paradigms they identified the main carrier branches and induced growth sectors, the key factor industries offering abundant supply at decreasing prices, the sectors growing quickly from a small basis, the limitations provided by previous techno-economic paradigms, the ways in which the new paradigm provides solutions to certain problems, and finally the organization of firms and types of cooperation and competition. Similar to Rostow, Freeman and Perez speak of a “period of transition” to denote the deep structural change in the economy requiring an equally profound transformation of the institutional and social framework (Freeman and Perez, 1988, p. 59).

Development economics

Development economics is concerned with barriers to and conditions for transitions from informal economies dominated by subsistence agriculture and local autarky to formal market economies involving market exchange, international trade and industrial activity. As a result, this field has many insights to offer on transitions, which would require a separate paper in itself to summarize. An important model is the one already discussed in the previous section by Rostow. Two other important ideas from development economics are backward linkages (Hirschman, 1958) and cumulative causation (Myrdal, 1957), topics which are being revisited by innovation economists in models of endogenous growth. Countries may get stuck in a low-growth equilibrium due to specialization in low-productivity techniques and sectors that generate few knowledge spillovers. Processes of catching up and falling behind have been studied by Fagerberg (1994) and Fagerberg and Verspagen (2002) in models of technological gaps where a gap that is too large inhibits the process of catching up. Dynamic processes associated with the way in which an equilibrium gets established have also been analyzed in expectation-based models where the relative importance of the past and the expected future is shown to depend on parameters like the discount rate and the speed of adjustment (Pardham, 1995).

The "history versus expectation" controversy is not resolved (Krugman, 1991). It is generally agreed that any type of coordination for higher growth is not an easy task. The role of government is being reassessed within the field of development economics: government policy is increasingly viewed as holding back development rather than promoting it, due to government failures. The role of the government escaping development traps continues to be debated. Whatever the government's role is, it is not simple, in part because development involves structural change and newly created capabilities that are difficult to manage. The use of foreign technology is not a real solution because of "tacitness and circumstantial sensitivity" of technology (Pardham, 1995). One lesson taken from development economics is that development defies precise control. Another is that it is difficult to manage adjustment processes, the interplay between macro-economic variables, and microeconomic processes. From development economics, transition research may borrow from the method of comparative analysis (of institutional arrangements such as good governance) and models of low-equilibrium traps (see Hayami, 1998).

There are several other relevant ideas within development economics. The Kuznets curve, an inverted U-shaped relationship between income per capita (horizontal axis) and income inequality (measured by, e.g., a Gini coefficient) formalizes that agricultural economies have a low level of income inequality, during early industrialization income inequality increases, while beyond a turning point inequality decreases (Kuznets, 1955). In an analogous manner, the notion of an environmental Kuznets curve (environmental pressure versus income per capita) has been examined, but has been shown to provide a less general result (de Bruyn and Heintz, 1999). Kuznets was also one of the first to suggest that the current developing countries were very different from what the western countries were before the time of industrialization. In other words, he stresses that the 'linear model' according to which all countries go through the same stages, is incorrect. Kuznets (1971) argued that various conditions are needed for development. Advancing technology is necessary but insufficient. Institutional and attitudinal adjustment – which might be called 'social innovation' – are also required. A number of changes characterize the development process: increases in average per capita income, total factor productivity and international trade and relations and, structural transformation of the economy, as well as social and ideological transformations.

There are many other concepts, proposals and models in development economics that are potentially relevant to transition research: structural change models (e.g., Lewis' 2-sector model of food production and manufacturing), international-dependence models (neocolonialism), false-paradigm model (not accounting for unique cultural, tribal, caste and institutional circumstances),

dualistic-development thesis (combination of modern and traditional approaches; of wealthy, educated elites and masses of illiterate, poor people; and of monetized markets and informal barter trade), coordination failures (market failures, lack of complementary and intermediate sectors, lack of specialized labour – e.g., O-ring theory), differing initial conditions (physical resources, human resources, climate, population size), neoclassical economics perspectives on market liberalization and internationalization, analysis of a range of other factors (demography, quality-quantity trade-off with regard to offspring, migration, foreign aid). See, for instance, Todaro and Smith (2003) for an introduction to these various ideas. It is therefore likely that most of the ideas currently generated by transition researchers are reinventions of older ideas by previous researchers of economic development.

Economic growth theory

Within neoclassical economics, the theory of economic growth offers the most clear and strong link with transitions. This theory includes a variety of approaches. One can distinguish between classical (Smith to Marx), Keynesian (Harrod-Domar, Meade), neoclassical (exogenous; Solow-Swan), endogenous growth theory (Romer, Lucas), and others (e.g., von Neumann). In addition, it is possible to identify positive and normative theories (Tinbergen, Cass-Koopmans, Ramsey, golden rules, turnpike), and multisectoral approaches (Uzawa). Policy relevant issues relate to convergence of growth rates and levels among countries, avoidance or undoing of poverty traps.

Transitions are characterized by non-linear developments. Transitions have periods when development is slow and at other times, fast. In theoretical dynamic models of growth theory, these features of a transition are recognized without having to specify micro-processes. In fact, 'transition' is used sometimes to denote the shift to a higher equilibrium growth path. In normative growth theory, transitions are associated with the 'turnpike' theorem. This theorem states that it can be optimal from an intertemporal welfare perspective to follow a (close to) maximally rapid growth path to allow an economy to move to a more satisfactory state quickly, despite consumption being lower during the transition than at the beginning or end of the period (Dorfman et al., 1958).

Stability is another aspect of growth theory. The neoclassical growth (Solow-Swan) approach ignores macroeconomic stability as it is assumed that planned investment always equals planned savings, and that the capital-output ratio can change through investment. The macroeconomic adjustment process that makes this true is omitted. The Harrod-Domar approach has a fixed capital/output ratio and generally no equality of savings and investment, and results in unstable steady-state growth. Essential for growth and development in the Harrod-Domar framework, is the proportion of income saved (not consumed), which will steer capital investment - the engine of growth.

A central concept in neoclassical growth theory is convergence. The Solow model (Solow, 1956) has provided the basis for examining convergence. Absolute convergence means that different countries with the same population growth rate, the same savings propensity, access to the same technology but different capital-labor ratios, will converge to the same growth rate, steady-state capital-labour ratio, output per capita, and consumption per capita. Conditional convergence means that countries which differ in savings propensities and capital-labour ratio, will converge to the same growth rate but not necessarily to the same capital-labour ratio and output per capita. The lack of convergence has been explained theoretically by invoking notions of technological and population induced poverty traps (a vicious circle of low savings and few investment opportunities). In this sense the (Malthusian) demographic transition is also relevant: as income per capita rises, the population growth rate rises.

Exogenous growth theory does not explain empirical facts of growth well. In particular, about half of historical growth could not be attributed to investments in production factors. This so-called 'Solow residual' was one reason to develop endogenous growth theory (Barro and Sala-i-Martin, 1995; Aghion and Howitt, 1998). An essential assumption here is that private and public

investments are associated with positive externalities (spill-overs) that undo tendencies of diminishing marginal returns on capital investment. Complementary investments in human capital (knowledge, innovation) and an optimal trade-off between human and physical capital investments are critical for this area of research.

Finally, two-sector models (with consumption and capital production sectors and intermediate deliveries) have received little and/or ad hoc attention. This is unfortunate, as they seem to be crucially related to transitions, in particular to understand structural changes in sector composition and interrelations. Endogenous growth theory has generated some two-sector models, but these are only meant to address the production and costs of innovations in a separate 'knowledge sector'. An original model is one in which the neoclassical rational agents and equilibrium are combined with vertical innovation or (Schumpeterian) creative destruction (Aghion and Howitt, 1992). All in all, the results of the enormous body of growth theory are a bit disappointing where transition research is concerned.

Economic history

We indicated in Section 1 that transition research would benefit from the study of historical transitions. This immediately supports the potentially useful role that economic history can play. In this field, all types of variables are interwoven into narratives (traditional approach) or combined in formal models (cliometrics). Economic history is much more data-driven than theory-driven. Theory is nevertheless implicit in the choice of explanatory variables and in the importance attached to certain variables and events. Mokyr (1990) has identified a long list of factors that he regards as crucial for successful technological innovations in economic history. Table 1 present a selection of the most important ones, which van den Heuvel and van den Bergh (2005) have divided into basic and side conditions. Although such a classification is helpful, it should be realized that the factors are not always independent. Factors may be strongly dependent on others in a certain region and during a specific time period. In any case, transition studies might systematically examine the state and role of these various factors.

Table 1. Fundamental innovation factors

Basic conditions	Side conditions
Level of nutrition	Geographical environment
Life expectancy	Demographic factors
Norms and values	Institutions, property rights, and regulation
Openness to information	Resistance to innovation (conservatism)
Willingness to bear risks	Science and technology
Religion	
War	

Note: Factors based on Mokyr (1990); own classification in two types.
Source: van den Heuvel and van den Bergh (2005).

Cliometrics, with its focus on quantitative analysis, might also be useful for understanding transitions. This type of study involves the application of economic theory and econometric-statistical techniques to understand regularities of economic history. Both Greif (1997) and North (1997) emphasize that this has advantages over narratives, even though a main limitation of the approach in the past has been associated with a strong reliance on foundations in neoclassical economics. North, however, is optimistic about using cliometrics to include such aspects as bounded rationality, transactions costs and changing preferences. In addition, a main problem to be resolved is associated with the linking of independent but often abundant data on economic, demographic, educational, institutional and technological variables. There is much to learn from past cliometric research, as major transitions have already received ample attention.

A famous example of this research includes Fogel's (1964) study of the transition from horse wagon to rail in the U.S.A.. Fogel argued that the common belief that railroads played an important role in overall American economic development at the end of the 19th century is overestimated. He suggested that the innovation of the railroad delayed the emergence of modern cars and trucks with combustion engines, for decades. In addition Fogel adopts a type of spatial economic perspective in assessing the impact of different (hypothetical) transport technologies based on spatial economic patterns.

An institutional-historical approach towards transitions is promoted by North (1981) in the analysis of the transition from primitive agriculture to modern intensive agriculture. North regards the move from common property (or better: open access) to exclusive property rights as the critical factor in the first economic revolution, because it allowed cumulative technological improvements that set the stage for a lasting period of high growth. Institutions may be composed of both formal (laws) and informal (social norms) rules of the game within a society (North, 1991). Modern economies require property rights, and effective, impersonal contract enforcement. Societies are less likely to develop and flourish when constraining formal or informal institutions limit the range of economic combinations possible. Unlike Rostow, North did not develop an economic model of a transition but focused on the role of political and economic institutions in reducing uncertainty and transaction costs in order to realize potential gains from exchange.

Another interesting historical study is provided by Wilkinson (1973), who developed an ecological explanation which linked the Industrial Revolution to natural resource factors (see also Common 1988). It recognizes a number of human strategies that respond to resource scarcity, such as new techniques, new resources, new goods, and migration. According to Wilkinson, the use of coal was stimulated by high prices of wood, following the significant loss of forest cover in England. In the early phase, coal was mined at strips at the surface. Later deep mines were explored. This in turn created an 'important' problem: the need to pump away groundwater, which gave rise to the first large scale, application of the steam engine. Widespread use of it gave rise to various refinements of the steam engine, alternative models and as such, new types of applications. In a next phase, spin-offs to other sectors occurred, especially to the textile industry and to transport's ships and trains powered by steam locomotives. Wilkinson´s work helped to reconfirm the importance of resource scarcity for human development and advanced a cause-effect view which is very relevant to transition processes. The earlier model by Faber and Proops (in the previous section) can be regarded as a crude formalization of Wilkinson's conceptual model.

Economic studies of transition economies

Since the 1990s much attention has been given to the transition from communism to market-democracy systems. This research was motivated by fundamental changes in the former USSR and east-European countries which have been taking place since the second half of the 1980s. Studies give specific attention to emerging markets (competition), institutions (property rights), transformation of public to private production, role of trust and independent media, entrepreneurship and investment, trade and foreign involvement. Economics of transition is now a well-developed field. In this field, there is unanimous agreement that institutions matter and that each country's evolution is unique.

There has been a fundamental debate between big bang and gradualist advocates, even though the knowledge basis is very thin. Economists have certainly underestimated the coordination problems of moving toward market-based systems (Gros and Steinherr, 2004). All European transition economies experienced a fall in output, for much longer times and more deep than originally anticipated. It required new models to explain this, with positive non-linear feedback (e.g., Rosser and Rosser, 2004). Countries that implemented reforms early on into the process usually were ahead of the others (Gros and Steinherr, 2004, p. 110). Reforms consisted of

price liberalization, privatization of property, liberalization of trade through removal of tariff and non-tariff restrictions, currency reforms, and macro-economic stabilization policies (to reduce inflation). Command-economy characteristics did, however, not disappear immediately or completely (path-dependency).

Within this genre of literature 'transition curves' are being estimated (Philips and Sul, 2005). Political economy aspects are investigated to explain differences in economic performance among transition economies in relation to the sequence of reforms (Roland, 2002; Kornai, 2005). The transition experience very much reinforced the institutional perspective in economics. It also stimulated people "to think about institutions not in a static way but in a dynamic way: how momentum for reform is created and how institutions can evolve, but also how momentum can be lost and how one can get stuck in inefficient institutions" (Roland, 2002, p. 47). The mainstream economics influence here is that governments should just improve the conditions under which decentralized decisions are made, i.e., let markets find the route towards the future (Hayek, 1978). All in all, much can be learned from this field for transition research.

Economics of technology

It is evident that the economics of innovation and technology address a number of issues that are relevant to transition research. This field is concerned with incentives and institutional mechanisms of knowledge creation and spillovers. Schumpeter is considered to be the founder of this field, at least where the definition of the issues is concerned. Ever since Schmookler (1966) innovation is seen as being responsive to economic stimuli with search processes being informed by engineering ideas that indicate what is worthwhile ('notional opportunities'). Later research on technological regimes found that innovation is not fully responsive to economic stimuli and occurs within certain patterns and constraints (Dosi, 1988; Malerba and Orsenigo, 1997). Innovation is found to be different across sectors and to be surprisingly similar across countries. This has to do with technological opportunities, appropriability conditions, degrees of cumulativeness of knowledge, and the nature of knowledge (generic versus specific, tacit versus codified, complex versus simple), as shown by Malerba and Orsenigo (1997).

Innovation is a very broad term, comprised of technological innovations, product innovations, and changes in markets, organisation, logistics and finance. Freeman and Perez (1988) make a distinction between incremental innovations, radical innovations, changes of technology system and pervasive changes in a nation's technological basis (changes in techno-economic paradigm). Rosenberg talks about minor and major innovations where major innovations are those that provide a framework for a large number of subsequent innovations. For transition research, an important distinction is between sustaining innovations and disrupting innovations (Christensen, 1997). Disrupting innovations are those innovations that render obsolete existing structures and systems (e.g. automobiles and minicomputers). These innovations often come from outsiders who are serving non-mainstream customers. Disruptive products tend to under-perform in mainstream markets but have certain features that are highly valued by specific customers (i.e., military and other idiosyncratic costumers for who performance is more important than price). As a product improves, it might then break out of its original, small niche and replace the dominant product, as happened in the case of gas turbines and more recently in the case of digital cameras.

A transition model of technology evolution is the lifecycle model of Abernathy and Utterback (1978). The transition is the shift of product innovation, to process and unit production, to mass production, following the establishment of a dominant design. This model applies to high-volume products and does not apply to all goods. In services there may be a reverse lifecycle (Barras, 1986), with product innovation succeeding process innovations (automation). The lifecycle model has been extended into an evolutionary model of variation, selection and retention by Tushman and Rosenkopf (1992). They distinguish two phases: an era of ferment (a time of competing

designs and organizations around them), and an era of incremental change. During all stages there is variation, selection and retention.

The economics of innovation is a broad field drawing on information and behavioural economics (learning, bounded rationality), organizational theories and system theory. Attention is given to wider issues besides the economic stimuli, that are shaping technical change. The notion of a national system of innovation model is an effort to understand the whole of factors shaping processes of knowledge creation and dissemination. Special attention is paid to institutions of science and education, to firm capabilities and to cultural issues. Companies are seen as embedded in innovation systems (or regimes) that guide, aid and constrain the innovation. The task for policy is not so much to create more competition but to set in motion processes of cumulative causation (Jacobsson and Bergek, 2004). To do so, policy should strengthen inducement mechanisms and deal with blocking mechanisms. Many blocking mechanisms exist. Attention is given to the dominance of existing systems that have benefited from learning processes and processes of adjustment and integration (Freeman and Perez, 1988, Kemp and Soete, 1992, Freeman and Louca, 2001).

A formal analysis of technological succession is being offered by Windrum and Birchenhall (2005). Increasing returns to scale are found to play an important role in successions, fitting in with empirical findings (for example of Klepper, 1996) that high start up costs are an important factor deterring new market entrants. A succession, a specific kind of transition, is found to be more than the displacement of old technology products by new technology products. It also involves the displacement of existing customer classes and preferences, the displacement of established market firms and established structures of production.

Environmental, resource and ecological economics

A transition to sustainable development cannot occur without good environmental regulation and resource management. The field of economics dealing with this is environmental (and resource) economics. Environmental economics addresses the economic analysis of the causes and the nature of environmental problems and their solutions. This includes issues relating to markets as well as to public policy. Environmental economics covers resource economics. The combination makes sense, since many resource issues are intricately linked to environmental issues. This is perhaps most noticeable in the case of fossil energy resources, the use of which contributes to the enhanced greenhouse effect. The notion of sustainable development, which has become one of the pillars of modern environmental economics, supports the linkage of resource and environmental problems. Closely related to environmental economics is ecological economics. It can be regarded as a social-science oriented version of environmental science. It has perhaps been most successful in promoting multidisciplinary research in which natural scientists (notably ecologists) and social scientists (notably economists) join forces.

The economic theory of environmental policy starts from the concept of "externalities" (see also the item "public economics"). Environmental economics is particularly interested in negative environmental externalities, i.e. negative physical effects of environmental pollution, resource use, or other types of environmental disturbance, such as fragmentation due to road infrastructure in nature areas, by one agent to another. Externalities have been analytically examined and discussed with the help of partial and general equilibrium theories, which is consistent with neoclassical assumptions regarding individual behaviour and operation of markets.

Instruments of environmental policy are traditionally evaluated in economics on the basis of their efficiency features. Effectiveness and distribution effects (equity, fairness) function as secondary evaluation criteria. The most common (archetypal) comparison is between uniform standards and taxes of pollution control. Taxes are attractive as they provide better incentives than standards to change individuals' behaviour, and thus realize more efficient outcomes: either social welfare is higher or costs of realizing fixed targets are lower. This is accomplished by

equalising marginal costs of pollution abatement, assuming that individual polluters are minimizing costs. Standards are especially attractive from the perspective of effectiveness (or uncertainty). A combined instrument is a system of tradable permits. This has two features - a ceiling is set on all pollution emissions of a particular type by granting a finite amount of emission permits and, permits are tradable. The first feature assures effectiveness, and the second efficiency. Taxes and tradable permits are dynamically efficient, as they provide a permanent incentive for cost-savings through innovations.

Environmental economists support transition research by studying the irreversibility of changes resulting from policy and/or a lack of policy. This has been addressed with option value theory (Arrow and Fisher, 1974). Decisions made in private markets do not lead to socially desirable use, allocation, transformation and conservation of nature and (scarce) land. This literature suggests that under certain conditions irreversible developments should be avoided or postponed until better information can be obtained. See Gollier et al. (2000) for linking this literature to the precautionary principle, and Pindyck (2000) for examining the notion of optimal timing for implementation of environmental policy.

An important and somewhat related idea, receiving much attention in ecological economics, is 'resilience', an extended stability concept. It has two definitions: (i) the time necessary for a disturbed system to return to its original state (Pimm, 1984); and (ii) the amount of disturbance that a system can absorb before moving to another state (Holling, 1973, 1986). Unlike most growth economists, whose models provide no upper bound on economic growth, physical scientists and ecologists are accustomed to the idea of limits. Ecologists are far less optimistic about substitution possibilities (of man-made capital for natural capital) than neoclassical economists, which is evident in the Holling view of sustainability which is really about maintaining ecosystem resilience. Diversity is important for resilience and for evolution.

Some authors have tried to find analogies of resilience in socio-economic systems. Static efficiency achieved through standardisation or tight control may reduce resilience (adaptivity) through reduced diversity. (see Levin et al. 1998; Gunderson and Holling, 2002). Policy implications are very different from those of standard economics: diversity is to be positively valued, one should be careful not to overexploit, and one should not exceed critical thresholds leading the system into collapse. This provides a bridge to evolutionary approaches which might shed light on the particular micro-level mechanisms involved in bifurcation and resilience (Rammel and van den Bergh, 2003).

Other ideas in ecological economics with relevance to transition research are coevolution and endogenous preferences, both having close connections to evolutionary thinking. Norgaard (1984) was the first to consider the application of the concept of coevolution to the interaction between economic and natural systems. His main illustration is the coevolution of pests, pesticide and environmental policy in the U.S.A. (e.g., Norgaard, 1994). Nevertheless, his ideas have been criticized for not indicating a sharp distinction between the interaction among subsystems ("co-dynamics") and strict coevolution as interacting populations with internal diversity causing mutual selection pressure (Winder et al., 2005).

The idea that preferences are endogenous instead of invariant has led Norton et al. (1998) to argue that changing consumer preferences can be in and of itself, an instrument of environmental policy. In particular they state that stable preferences are at best realistic over short periods of time, and that sovereign preferences are inconsistent with long term goals of sustainability. Consequently, public discussion about ethical consumption and sustainability should be stimulated via education, advertising rules, cultural norms, etc. Changing consumers' preferences through democratic processes could be used to encourage environmentally conscious consumption in a way that consumers would not feel "... deprived and unhappy ..." but "... enlightened and happy after being educated into the joys …"(Norton et al., 1998, p203). Most democratically elected governments have already formulated public policies aimed at influencing norms which are regarded as criminal, racist or otherwise undemocratic, so why not extend this

practice towards environmental sustainability? A demand side perspective is a useful addition to the dominance of innovation and R&D supply-side oriented policies, necessary to realize complex transitions.

Industrial economics

It is important to understand the behaviour of firms, their responses to incentives and regulation, and the interaction between firms in markets when trying to stimulate transition processes. Industrial economics offers relevant insights, being an extension of the theory of the firm to address a number of firm-internal and firm-external issues in a theoretical manner (e.g., Martin, 2001). This includes attention to market type (monopoly, oligopoly, etc.), vertical integration, price strategies (multi-product pricing, intertemporal price discrimination), product differentiation, price-quality trade-off and advertising, strategic behaviour and interaction between firms, the role of capacity constraints and investment strategies, rent seeking, complementary and networks, and asymmetric information affecting management and competition. For transition research especially long term issues like long-run, sunk and transactions costs, long (vs short) run price competition, barriers to entry and entry deterrence, exit, market contestability (threat of competition for incumbent firms by potential entrants), and R&D strategies are relevant when conducting transitions research. The policy angle within industrial economics focuses on antitrust legislation and other regulation to overcome various market failures related to imperfect markets (notably, collusion), incomplete and asymmetric information, standards and lock-in, and innovation externalities (patents, subsidies). A more empirical and statistical branch addresses the demography of industries (Carroll and Hannan, 2000).

Path-dependence and lock-in

A specific concept on the boundary of economics of technology, evolutionary economics and industrial economics, is path-dependence. This concept is highly relevant for transition research, as one can regard the essence of the transition problem to be the un-locking of a locked-in socio-economic-technological-institutional system. Path-dependence is intricately linked to lock-in. Moreover, lock-in has been one reason, additional to already recognized 'market failures', for believing that markets do not generally lead to (socially) efficient, or otherwise desirable, outcomes. Whilst markets encourage efficiency in production, the long-term outcomes may not be the most efficient when demand and supply are characterised by increasing returns. Regulation of environmental externalities may not have the intended effect of moving to an alternative technology or product associated with less environmental pressure. A technology that has achieved an early advantage may dominate or capture the market due to increasing returns to scale, according to a kind of self-reinforcement process, i.e., a larger market or market share stimulates relatively high growth. Increasing returns to scale take a number of forms:

- (Traditional) scale economies: cost and price decrease as the scale of production increases.
- Learning by using or doing: improvement, lower costs (producer), better performance (consumer).
- Imitation or bandwagon effect: rather than innovate, companies may imitate the most successful product, and the popularity of a certain good may propagate (as with fads).
- Agglomeration effects: spatial spillovers, easy communication and short transport distances that give rise to positive externalities.
- Network externalities: being connected to a larger network (e.g. via phone) often has an advantage.
- Financial power: the more a product or technology is adopted, the more resources will be available for its development and perfection, which, in turn, will make it relatively attractive for potential adopters.

- Informational increasing returns: if a product is adopted more, and therefore becomes better known, then risk-averse individuals will more easily be convinced to buy it.
- Technological inter-relatedness or complementarity: infrastructure and sub-technologies are often complementary (gasoline, refineries, filling stations, car technology). This relates to the importance of coevolution of complementary factors (knowledge, technology and institutions).
- New knowledge is shared by firms: firms increase knowledge due to learning-by-doing and innovation, which can be shared with other firms in the same sector with similar problems. This leads to dynamic increasing returns at the level of industries.
- The political power of vested interests, operating, among others, through lobbying in politics.

Due to these mechanisms, formally studied by Arthur (1988, 1990), a technology with a large market share, due to an early start, has an advantage and as such can grow relatively quickly (attain an even larger market share), even without any intrinsic (cost or net welfare) advantages. An important consequence of increasing returns is that the (adoption) process towards the final or equilibrium state of the system is path-dependent (non-ergodic). Path-dependence can be interpreted as temporally remote events having a significant or dominant impact on the present: the logic of the world can be understood only by uncovering how it got this way (David, 1985). Path-dependence thus implies irreversibility. It should be noted, however, that path-dependence is not the consequence of purely random factors, but results from interaction between random and systematic or deterministic, notably selection, factors. Contingency interacts with historical selection forces, with the latter probably being more important. In the words of historian Landes: "big processes call for big causes". This fits with the transition perspective of Rotmans and others who assert that mutually sustaining developments at different levels (niches, regimes and landscape) are necessary for a transition to occur.

Path-dependence can result in lock-in. Lock-in occurs when a dynamic pattern of competing technologies ends up in a situation with one technology dominating the market. Heterogeneity of user needs and other types of heterogeneity (at the supply side or otherwise) usually mitigate against this but, in the case of large increasing returns, as with network technologies, there is a danger of becoming locked into particular solutions. A situation of lock-in can persist for a very long time, as happened with the QWERTY typewriter (David, 1985) and the light-water nuclear reactor for electricity production (Cowan, 1990). It can be argued that the use of fossil fuels constitutes an example of lock-in. The latter is relevant to the transition to a sustainable economy and energy system.

Apart from the economic sources of lock-in we have institutional and cultural path-dependency, meaning that institutions or cultural habits are fixed and cannot be changed easily (Unruh, 2000, 2002; Kemp, 1994). Any transition requires new institutions and new forms of alignment, which take time and effort. They are not controlled from a central point but the result of distributed agency and entrepreneurship. In the establishment of a new path, a multitude of actors becomes involved with a technology and generates inputs that result in a transformation of an emerging technological path (Garud and Karnoe, 2003). In the early period when the technology is in a flux, social, organizational and political factors are important shapers of technical change, later on 'technology' becomes a determining factor, with technological imperatives setting the conditions for competition (Tushman and Rosenkopf, 1992; Molina, 1999). In conclusion, it can be said that any new path creates new path-dependences.

Public economics

Public economics is the sub-discipline within economics that provides the most general perspective on public policy, in terms of the conditions under which public intervention is required as well as the form policy should take (institutional arrangement, policy instrument

type). Likewise, public economics can shed light on certain aspects of transition management, notably where these relate to solving public goods and externality type of problems. Pure public goods are characterized by non-rivalry and non-excludability in use. However, many mixed type of private-public goods are found, namely where rivalry is not perfect due to congestion beyond a certain threshold, or where property rights take different forms (common, state, clubs). To make things more complicated, both rivalry and excludability may sometimes change due to technical progress (e.g., technical exclusion or inclusion, e.g., allowing the whole world to see a particular football match).

A number of public goods are relevant in the context of transitions. One is knowledge, which is a quasi-public good. It is non-rivalry in use but people can be excluded from it, through secrecy and patents. Much public investment in knowledge is undertaken most notably through universities and related institutes. Certain goods require physical infrastructure for their use. Historically government plays an important role in the provision of such infrastructure but it can also be provided through private capital if the costs of using it can be charged to the users (e.g., toll roads). Public-private-partnerships offer a mechanism to transfer the risk and debt associated with these new capital projects to the private sector in return for a long-term service contract. Property rights typically remain with government.

Externalities are unintended and unpriced (outside markets) effects exerted by one economic agent onto another, affecting his/her utility or profit. Externalities come in both negative (e.g., environmental pollution) and positive forms (R&D or knowledge benefits). The fact that individuals make decisions without concern for externalities – by definition – means an outcome that is not consistent with the highest attainable level of social welfare. Regulation is therefore required. Negative externalities need to be suppressed (optimally with good taxes, levies or tradable permits) while positive externalities need to be responded to with subsidies or patents.

Next to policy, self-regulation or evolution of social norms of common-pool resources can be an effective mechanism (Ostrom, 1990). This can occur through local interactions among users that involve monitoring and (altruistic) punishment. Externally or hierarchically imposed regulation can destabilize co-operation, notably when associated hierarchical monitoring is imperfect. Stimulating norms through communication may then be more desirable. Instability in the evolutionary equilibrium can also arise when certain parameter or external changes occur. Examples are: sanctions decline, harvesting becomes more efficient (technical progress), the resource price alters, resource users migrate, external economic and political events, and natural disasters influence the resource quality and processes.

Finally, public choice theory clarifies how public decision making and policies are influenced by special interests through lobbying and negotiation. In addition, it recognizes that a government is not a homogeneous group or analogous to a single decision making individual, but is composed of various individuals or groups (civil servants and politicians) with possibly conflicting interests and goals (Dietz and Vollebergh, 1999). This is of relevance to transition research, where it is often stressed that important barriers to transitions are created by power and vested interests of specific stakeholder groups.

Spatial economics

Transitions involve heterogeneous spatial processes as well as complex spatial interactions. Spatial issues are studied within spatial economics, which is an amalgam of regional, urban and transport economics. Spatial economics cover issues that use the approach of neoclassical economics and approaches common to the study of technological innovation and spatial diffusion, to understand spatial economic regularities. Important insights of this field for transition research relate to the location of industries, urban and regional markets, spatial externalities (both negative and positive - innovation and agglomeration related), spatial patterns of diffusion, regional diversity, regional isolation, regional (open system) dynamics, and

economic effects of infrastructure. Recent development in new economic geography furthermore link up with international economics (Krugman, 1991).

One only needs to refer to the problems associated with non-point source (diffuse) pollution problems, land use and biodiversity loss, specific urban environmental problems (noise, health problems, congestion), and the impact of stringent environmental regulation on location choice, trade and transport (Siebert, 1985; van den Bergh, 1999, part V), to understand that the interaction between environmental policy and spatial economic analysis is relevant.

The interaction between technological innovation studies and spatial economic analysis has focused on regional development, spatial diffusion of innovations, and diversity and isolation of regional initiatives (Malecki, 1997; Acs, 2003). Insights about the functioning and boundaries of urban and regional markets – for products, services, housing, labour, and transport – may moreover be useful when searching for niches and diverse industrial trajectories. Agglomeration effects may be important as well, similar to the role played by positive externalities in endogenous growth theory. Fostering agglomeration means stimulating shared inputs (labour pool, knowledge) at relatively low costs. In addition, public infrastructure and capital may be crucial (i.e., roads, public transport, parking facilities, communication systems, and attractive nearby living conditions). An important question with regard to public investment in infrastructure is whether it stimulates new development and innovations or just leads to relocation of existing activities (Eberts and McMillen, 1999).

From a policy perspective, a number of issues are relevant. Diffuse pollution might require input regulation rather than direct pollution regulation. The Tiebout hypothesis is relevant (Tiebout, 1956) with respect to local public goods. This hypothesis points out a mechanism of self-organization at a higher spatial level by suggesting that local public goods may differ and in turn cause migration ('voting with the feet'). Implementing land use taxes will affect the cost of using land, which in turn will influence location choices by firms and households. Henry George suggested already in the 19th century to tax the rental value of land. This will generate revenue that benefits the community instead of the individual private landowner. Very often the price of land is high simply because of positive externalities generated in the surrounding area by attractive places and services (Cohen and Coughlin, 2005). Likely consequences of a single (Georgian) or two-rate land tax are an improved quality of land and buildings, shorter transport distances, and less urban pollution. Such land taxes can possibly contribute to a transition to sustainability.

4. A summary of contributions from economics

Given the broad scope of this article it is impossible to provide a complete overview. Nevertheless, it is worthwhile to try to identify the most exciting theories and concepts that economics has to offer for transition research. Table 2 outlines the results of our efforts. Its point of entry indicates the type of problems that one typically experiences while studying transitions, whether reflecting into the past (history) or visually the way ahead (future). The table summarizes the main approaches and concepts by identifying a list of core transition challenges in the first column, and then relating these to economic approaches. Relevant concepts of these approaches are listed and where necessary, comments are provided to indicate if there is a requirement to elaborate further on the approach or concept(s) as they relate to the respective transition challenge. The table is not perfect as it assumes a decomposition of transition challenges, which in reality are often connected and interactive. Similarly, sub-disciplines of economics are not entirely independent, but overlap in terms of problems studied, concepts used and solutions offered. That said, the table serves a useful function by providing guidelines for the reader interested in transitions research and the schools of economics that seek solutions to the problems specific to transitions.

Table 2. An overview of economic theories and concepts relevant to transition research

Transition challenge	Useful economic approaches	Relevant concepts	Need for elaboration
Barriers	Grand development theories, Economic history, Evolutionary economics, Ecological Economics	Resilience, lock-in, learning by using or doing, imitation, network externalities, technological inter-relatedness (complements), vested interest (rent-seeking)	+
Supply side	Economics of technology, Industrial economics, Grand development theories	Market failures, scale economies, innovation strategies, cooperation, networks, complementary products, vertical integration, rent seeking, demography of industries	0
Transition dynamics	Long waves, Economic history, Macroeconomics, Growth theory, neo-Austrian economics, Development economics, Economics of disasters	Increasing returns, life cycle, competition, multi-stages, shocks, disasters (natural, economic, war)	++
Innovation tempo	Economics of technology, Evolutionary economics, Economics of information	Patents, subsidies, market niches, experiments, diffusion, adoption, innovation systems	+
Demand side	Marketing, Behavioural economics	Habits, imitation, lexicographic preferences	++
Externalities	Public economics, Environmental economics	Public goods, club goods, regulatory instruments, efficiency	0
Diversity	Evolutionary economics, Economics of technology, Economics of information	Short term efficiency, long term innovation, increasing returns, adaptation, flexibility, real options	+++
Spatial organization	Regional and urban economics	Location, Tiebout hypothesis, agglomeration effects, transport, infrastructure, regional diversity, spatial isolation, trade	++
Institutional conditions	Institutional economics, Public economics, Economics of transition economies	(Intellectual) property rights, education, science, legislation, markets, culture and behaviour (norms and values, risk attitude, conservatism, religion), regulation	++
Knowledge	Economics of information, (Endogenous) Growth theory	Asymmetric information, learning, search, uncertainty, expectation, positive externalities, network formation, informational increasing returns	+
Role of private firms	Industrial economics, economics of information	Competition, market failures, investment conditions, uncertainty	0
Role of government(s)	Public economics, Environmental economics	Government failures, market (self-organization), public investment (infrastructure, R&D), removing uncertainty (insurance), conflict resolution	++
Demography	Population economics	Education, labour force, productivity, risk attitude	+

5. Evaluating mainstream economics from a transition research perspective

So far we have looked rather constructively at the theories, concepts and insights economics broadly offers a potential contribution transition research. It should be acknowledged, however, that some authors have emphasized that the dominance of mainstream or neoclassical economics provides a barrier to understanding and perhaps even fostering urgently required transitions, and that it conflicts with the 'transition (management) paradigm' (Rotmans, 2003). A problem in assessing the value of the latter statement is that this 'paradigm' has not yet crystallised out (RMNO, 2003). Indeed, it is still characterised by a diversity of opinions and a loose set of ideas without firm and consistent theory and associated formal models. In fact, this incomplete development of transition theory underlines the usefulness of examining what the contribution of economics might be to understanding and managing transitions.

The question therefore is this: how well suited is neoclassical economics for the study of long term transitions. A quick judgement might be that neoclassical economics is too concerned with economic variables, prices and income effects, and is missing out on the cultural, institutional and structural aspects of economic change. In defence of neoclassical economics, apart from what was already noted in section 3.1, we can say that especially general equilibrium models provide a complete structure of how prices and quantities of all the goods are linked together. A transition involves large changes, with effects that permeate the economy (among others) through price and cost structures. In this respect, the neoclassical economic approach provides a firm tool for calculating the impacts of structural change. Economists prefer to separate out only a few cultural and institutional aspects but this does not mean that they are not part of the equation: they are implicit in the demand and cost specifications. The economist's way of viewing the world is in terms of markets (demand and supply interaction) for labour, capital, other input factors, and goods and services. These various kinds of markets interlock, which is described in the most complete manner in general equilibrium models. Markets solve complex coordination problems of distributed knowledge by signalling relative scarcity thereby guiding the plans of economic actors at the supply and demand side. This is what economists are preoccupied with. Neoclassical economics cannot provide the complete picture of transitions. But this is hardly a serious criticism. No single theory can cover the entire spectrum and complexity of long term transitions. .

Nevertheless, one can wonder whether dominant approaches in economics include the right variables and processes, and employ the correct behavioural assumptions, to study long-term transitions. The relevant processes will differ from case to case, as is already clear from the typology of transitions by Geels and Schot (2005). Economic studies may especially be criticised for giving little attention to changing institutions, which often will imply altering model parameters or structure. In order to identify and analyse the various transition processes as well as incorporate institutional dimensions, collaboration between economists, sociologists, business historians and other social scientists might be useful.

In addition, non-linearities and discontinuities play a role in transitions. Examples are the creation of new products and the emergence of institutions through agent interactions. Traditional equilibrium models with representative agents tend to underestimate such interaction effects. In this respect, agent-based models are more flexible and powerful. They allow for addressing gradual changes in the degree of interaction (or coordination) or gradual changes in behaviour, which in turn can lead to discontinuous changes (Rosser, 1999). Moreover, whereas the micro-foundations in mainstream economics emphasise upward causation, a more realistic approach might be a combination of upward and downward causation (van den Bergh and Gowdy, 2003). The latter seems to be consistent with the multilevel transition framework. It provides an opportunity to incorporate difficult issues relating to emergent phenomena, such as network and group formation and, appearance of new norms.

Coevolution theories appear useful when attempting to understand the complexity of transitions. The transitions studies by Geels (2005) show that the relations between niches and regimes can be complex: existing regimes can make new niche developments difficult through competition with the established regime; niche development can, however, occur within a dominant regime (e.g., gas turbines were used within a coal regime before they overtook it); and niches outside a regime may benefit from certain regime features (e.g., the use of roads by non-motorized transport).

Finally, economics has been criticized to be focused on efficiency or cost-effectiveness, cost-benefit analysis, and optimality and smooth changes, in contrast with transitions that involve uncertainty and discrete jumps. This view, however, oversimplifies matters. Even though in practice many people and firms focus on strategies that reflect short term efficiency (e.g., more attention for energy conservation than renewable energy), economic theory does not imply this. Neoclassical economics does not exclude a search for solutions that satisfy long term efficiency (e.g., possibly renewable energy). It is true, perhaps, that efficiency is often approached in too deterministic a manner, giving too little attention to uncertainty and irreversibility. On the other hand, advanced approaches to evaluation in economics, such as option value and real options theories, do address uncertainty explicitly (Dixit and Pindyck, 1994; Fisher, 2000).

Perhaps more important is that neoclassical economics assumes rational agents that show optimal behaviour. According to an evolutionary perspective, dynamic efficiency through new economic development may evolve from initially sub-optimal behaviour, namely from actors doing something different. As Peter Allen has said: "In an evolutionary landscape of hills and valleys representing levels of functional efficiency of different possible organisms, it is the error-maker who can move up a hill, eventually out-competing a perfectly reproducing rival. And this despite the fact that at each and every instant it would be better not to make errors, since the majority are loss-making" (Allen, 1988, p. 107). Diversity is to be positively valued. The yardstick of (short-term) efficiency for policy action may not always be a good guide in an evolutionary world. Short term efficiency and long term efficiency may conflict, and diversity is in between. Neoclassical economics, however, does not attach value to diversity, but rather sees it as a cost. Incorporating diversity and the related themes of path-dependency (seen as irreversible change of diversity) and lock-in (seen as minimal diversity) into mainstream economics could mean an important contribution to transition research.

Finally, economics has stressed that there are several market failures which cause a deviation between market outcomes and social welfare optima. These market failures include:

- Missing markets: no markets for all goods and services.
- Imperfect competition on some markets.
- Economic activities generating externalities.
- The existence of public goods.
- Property rights being incompletely assigned.
- Transactions not occurring under perfect information.
- Bounded rationality: cognitive limitations and routines preventing firms from maximising profits and individuals from maximising their utility.
- The presence of transaction costs.

These various market failures have clear responses in terms of governmental policy or regulation. Economics offers concrete suggestions. In as far as transitions are hampered by such failures, economics can thus offer solutions. The most important lacking (system) failure seems to be path-dependence and lock-in, but even in this case economists have been able to convert it into the neoclassical paradigm, namely as increasing returns to scale, i.e., a kind of positive externality (Gerlagh and Hofkes, 2002).

6. Conclusions

The broad discipline of economics with its various sub-disciplines has much to offer for transition research. We have provided a broad overview here, without trying to create any personal selection bias, but instead allowing the reader to identify the concepts and theories of interest to facilitate stream-lined access to the specific economic literature that is relevant to certain aspects of transitions research. A disadvantage of our approach is of course that it skims the literature, and as a result is abstract and brief in its account of concepts and insights. This approach is intentional. Only a book format might overcome this shortcoming.

It may come as a surprise to non-economists involved in transition research that economists in the past have already generated many ideas that relate to transitions. For example, they have elaborated in great detail the notion of multi-stage development (notably Rostow), which seems to be reiterated in recent multi-stage theories. Economics can make many useful contributions to the study of transition. Perhaps the greatest contribution economics can make to transition research concerns the role of markets and limitations of planning in transitions, and the choice of instruments of environmental regulation. For dealing with public 'bads', such as pollution, economists favour market-based instruments such as pollution taxes and emission trading systems. They help to deal with them in a decentralized manner by not prescribing choice, which helps to achieve total reductions in pollution in a low-cost manner. Institutional economics can help make visible undesirable incentive structures and propose alternatives. Spatial (regional, urban and transport) economics provides many insights about the geographical and multilevel nature of economic activities and mechanisms. Path dependency may be analysed through evolutionary-economic models that allow for the understanding of the processes of lock-in at the micro-level. In addition, economic models might be elaborated to address multi-level aspects of transitions, including processes at the level of niches, regimes and landscapes. Diversity might be given a place in economic analyses to move from short term to long term efficiency, thus allowing a trade-off of short-term costs of diversity (keeping options open) with long term benefits (because diversity generates new options in the future). Bounded rationality (habits, routines, imitation, rivalry, group norms) may receive more attention in economic analyses, as this often provides a more realistic depiction of the response of individuals to complexity and uncertainty, which is relevant in certain transition phases.

We have briefly addressed the potential friction between the dominant neoclassical school in economics and the aims of transition research. Some writers in transition research have noted this potential friction. Our position is that certainly neoclassical economics does not offer the complete perspective on transitions that a concrete, formal theory does. Neoclassical economics offers useful information on market processes and economic motives, but tends to neglect or treat implicitly cultural and certain institutional aspects of transitions. It can provide insight into the how transitions will indirectly affect the economy through interacting markets, prices, costs, sectors, and demand and supply, with implications for labour, capital and other input factors. This appears to be a promising area for transition research, in which models of transitions to a market economy can play a useful role. As to the issue of achieving welfare benefits through system innovation, some critics have suggested that the economist's focus on efficiency or cost-effectiveness, using the tool of cost-benefit analysis, which prevents the search for uncertain, long term and discrete or non-smooth solutions and changes, and which means that there is no specific role for transition management. We feel that this oversimplifies matters. Economic theory does not prescribe short-term efficiency or optimisation. These are outcomes of the myopia of people, firms and governments that want to reap the benefits of investments as soon as possible. This exemplifies itself, for example, in the greater concern for energy conservation than for renewable energy. Perhaps efficiency is often approached in a too deterministic way, but on the other hand economics has developed advanced formal theories and models to deal with uncertainty and irreversibility, notably option value and real options theories. Perhaps what needs to be done is to extend these approaches to include the potential, future value

of diversity, so that ultimately a good trade-off between diversity and short run efficiency is feasible. Last but not least, economics has recognized the problems associated with path-dependence and lock-in. They are in fact considered one of many market failures, namely as a positive externality. A third possible critique on mainstream economics is the assumption of perfectly rational agents giving rise to optimal choices and social outcomes (in theory). Here perhaps lies the weakest element of mainstream economics, which is currently under attack from the fields of behavioural, experimental and evolutionary economics, all of which offer useful alternative ways to approach market and strategic interaction and public regulation, for transition research.

Economics is concerned with optimality but is generally critical about planning as a way to achieve this. Governments should just improve the conditions under which decentralized decisions are made. The main contribution of mainstream economics is then perhaps that it offers specific insights about how to respond to a number of market failures that hamper transitions. Economists and technology researchers and historians seem to agree that governments cannot and therefore should not try to pick winners. It is better to rely on the (evolving) self-organisation capacity of institutions and markets, even when the operation of markets may occasionally lead to sub-optimal solutions through path-dependence resulting in a lock-in. Evolutionary economists would next to selection by markets see an important government role for stimulating or even contributing (through public R&D) to a variety of options, precisely because markets are myopic and guided by increasing returns to scale, thus running the risk of fostering (too) early lock-in.

Given the rich set of concepts, ideas and approaches identified here, economics without any doubt can play a useful role in transition research. Of particular interest are the sub-disciplines of business cycle theory (long waves), development economics, economic history, economics of transition economies (former communist countries), economics of technology, environmental economics, institutional economics, public economics, and spatial economics. In view of this, a fruitful strategy would be to transfer relevant insights from each of these areas to transition research, and where relevant elaborate and synthesise them. This strategy would ideally involve interaction with experts from each of the sub-disciplines.

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